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APPLICATION FOR LETTERS PATENT

for

IMPROVEMENTS TO KLYSTRON-TYPE DEVICES

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TITLE OF THE INVENTION

IMPROVEMENTS TO KLYSTRON-TYPE DEVICES

PRIORITY CLAIM

[0001] This application claims the benefit of the filing date of United States Provisional Patent Application Serial No. 60/446,831, filed February 11, 2003, pending.

BACKGROUND OF THE INVENTION

[0002] Field of the Invention: The invention relates to Klystron and TWT devices which have a magnetically focused electron beam, including electrostatically focused beams.

[0003] State of the Art: Klystron devices, for example, with electrostatically focused beams have been constructed with focusing lenses rather than permanent magnets such as that illustrated in FIG. 1.

[0004] U.S. Patent 5,821,693 illustrates and describes a recent improvement in Klystron construction. Magnets, either permanent or electrostatic are brazed to the external surface of a tube. These magnets must be placed by hand in a precise manner and then brazed in place. Precise placement by hand is difficult and brazing limits the temperature at which the Klystron may be operated.

BRIEF SUMMARY OF THE INVENTION

[0005] Improved infrastructures for electron beam containing cavities has been invented. Ladder-like structures made by photolithographic/micromachining processes to form miniature ladder-like structures capable of being nested provide significant improvement in weight and power amplification for Klystron and TWT devices.

[0006] The precise structures are made by applying a precise mask by photolithographic technique and etching the substrate, generally an electroconductive metal, to form ladder-like structures of precise dimensions. The unremoved portions of the sheet form a ladder with spaced rungs and parallel rails. The spacing between rungs has micron-rigid tolerances and the spacing is such that rungs form an elongated ladder-like structure may superposed and interspersed with sufficient air gaps to prevent arcing or shorting.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

[0007] In the drawings, which illustrate what is currently considered to be the best mode for carrying out the invention:

[0008] FIG. 1 is an illustration of a prior art Klystron device with electrostatic focusing lenses;

[0009] FIG. 2 is a perspective view of a single ladder-like structure made by micromachining techniques;

[0010] FIG. 3 illustrates two ladder-like structures in a face-to-face relationship;

[0011] FIG. 4 illustrates schematically a second set of ladders shaped and structured to nest between rungs of a first pair of opposed ladders forming an elongated tunnel; and

[0012] FIG. 5 illustrates a hinge's dual-ladder structure whereby a precise tunnel may be formed by folding one ladder over the other along the hinge axis.

DETAILED DESCRIPTION OF THE INVENTION

[0013] Improvements in the fabrication and structure of electrostatically (ES) focused Klystrons have been achieved by employing microfabrication techniques. Unique, precise infrastructures for Klystron and TWT devices may be readily fabricated to have low, micron-sized tolerances. The infrastructures further permit multi-cavity devices of miniature dimensions to be made thereby providing high amplification devices which are small in size and light in weight.

[0014] Unique, elongated ladder-type structures which are formed as identical pairs are placed together to form an elongated tunnel (electron cavity). The ladder-like structure is illustrated in FIGS. 2 and 3.

[0015] FIG. 2 is a perspective view of a single ladder-like electroconductive structure wherein the cross-members (rungs) are recessed from the plane of the elongated ladder rails.

[0016] FIG. 3 shows two ladder-like structures positioned in a face-to-face relationship to create an elongated tunnel having a hexagonal, cross-sectional shape.

[0017] A second set of ladder-like structures of a similar shape to the structure shown in FIG. 2 is superposed on the opposed structures of FIG. 3 whereby the rungs are sized and shaped to fit between the rungs of the structures in FIG. 3. The gaps between rungs of the FIG. 2 structure

must be sufficiently wide to accommodate rungs of a second superimposed ladder so that the rungs of the second ladder are interspersed between the rungs of the first ladder with sufficient space on either side of adjacent rungs to prevent arcing or shorting between rungs.

[0018] The rails of the second superposed "ladder" are preferably separated from the rails of the first "ladder" by an electrical insulating material. The rungs of the first and second ladders may be of the same or slightly different dimensions. Each set of ladders will preferably have substantially the same geometric shape for its rungs. Opposed rungs forming a hexagonally shaped, elongated cavity are readily formed although the rungs could be half circles, e.g., so that a cylindrically shaped tunnel could be formed. Also, a tunnel with square or rectangular cross-sectional shape can be readily constructed. A hexagonally or octagonally shaped tunnel is preferred since a more uniform magnetic field can be created where the tunnel cross-section more closely approximates a circle.

[0019] Thus, a compact precise tunnel may be formed from four ladder-like structures of an electro-conductive material, e.g. copper, moly and similar conductive metals as well as conductive ceramics, silicon and the like.

[0020] One pair of ladders, top and bottom, with rungs directly opposed to one another is connected to an alternating current of RF frequency to create an electrostatically field (magnetic field) within the tunnel to maintain a beam of electrons flowing from an electron gun cathode in a tightly confined beam. The other pair of ladders, top and bottom are connected to a slow wave source of a.c. The slow wave current, in a simusoidal wave preferably, creates a field which causes bunching of the electrons, causing the electrons to slow.

[0021] The energy lost by the slowing electrons is captured by an RF field projected by a transmitting antenna located near the front end of the tunnel with a receiver antenna located near the beam discharge end of the tunnel. Thus, as shown in the attached tables, significant amplification of the RF field results from a Klystron having the ladder-type structures forming an electron beam tunnel.

[0022] The construction of a pair of opposed ladder-type structures is facilitated by forming such a pair from a single sheet of material having an elongated hinge whereby the axis of rotation of said hinge is parallel with the central longitudinal axis of the tunnel formed by folding one ladder-like structure over its twin along the hinge joint to form a structure such as that shown in

FIG. 5. This novel structure facilitates ready alignment of one ladder with an opposed ladder to form an electron beam tunnel. A hinged structure is illustrated in FIG. 5. The pair of interlacing, superposed ladders may also be made from a single sheet of material with a hinge joint.

[0023] Design of TWTA with Electrical Focusing System

[0024] Structure instruction

[0025] 1. Dimensions

[0026] All dimensions are scaled from Kory's structure according to pitch ratio except the following:

[0027] Short position given in the table;

[0028] Dielectric constant of cube 4.1;

[0029] Inserted electrical focusing system:

a. Thick of plate: 0.09807 mm;

b. Distance to waveguide side wall: 0.09807 mm;

c. Distance to waveguide bottom: 0.09807 mm.

[0030] 2. The electrical focusing structure

[0031] The two plates are connected together by ladders and in the same positive potential, and the waveguide are grounded. We have another version in which the two plates are separated and not in same potential as well as waveguide not grounded, which will be released in the future if necessary.

[0032] In the electrical focusing structure, the original ladders are cut every another required by the focusing voltage. The functions of the plates provide a big capacitance for the compensation of displacement current as well as the supporting mechanism. The outlet of the electrical plates are through the two small cubes, which can be found under the plates. The simulations show that there is no significant RF performance influence from the two ports, largely because of the plate capacitance function.

[0033] 3. RF performance influenced by electrical focusing structure

[0034] It is noticed there is significant influence by the introduction of electrical focusing structure. The significant influences include the increased dispersive, increased wave length or wave speed (resulting in a higher required anode voltage), increased attenuation, as well as increased deformation of waveform in space (or space spectrum). Efforts have been made to reduce the side

effect as small as possible. However, up to date the performance can not be thought as optimum. The future work will be needed depending the feedback from other engineer who performs the process.

[0035] The structure is intended for the design of V band, however in principal this design can be extended to Ka band by the structure scaling according to frequency ratio. We can evaluate the feasibility roughly, and then move further if necessary.

[0036] Table 1: Performance Table

Pitch = 0.190221978 mm

Frequency	51 GHz	52 GHz
Slow wavelength λc	1.3319 mm	1.1463 mm
Phase shift per cavity	51.41°	59.73°
Slow wave velocity Vp	0.679 E8 m/s	0.596 E8 m/s
Attenuation per cavity	0.18 dB/per cavity	0.29 dB/per cavity
Interaction impedance Zc	165 Ω	152 Ω
Required anode voltage to match wave speed	13,000 v	10,000 v
Gain parameter C @ ia=60 mA	0.0575	0.061
Gain of 64 cavities	3.78 dB	2.58 dB
Gain of 70 cavities	5.03 dB	3.71 dB
Gain of 80 cavities	7.11 dB	5.61 dB
Gain of 90 cavities	9.19 dB	7.50 dB
Gain of 100 cavities	11.28 dB	9.4 dB
Gain parameter C @ ia=80 mA	0.0672	
Gain of 64 cavities	6.28 dB	5.67 dB
Gain of 70 cavities	7.77 dB	7.09 dB
Gain of 80 cavities	10.24 dB	9.47 dB
Gain of 90 cavities	12.71 dB	11.89 dB
Gain of 100 cavities	15.18 dB	14.22 dB
VSWR at input port	1.38	1.29
Short position from axis	2.888 mm	2.888 mm

[0037] Magnetic Field Focusing in TWT Slow Wave Structure

[0038] The simulations of beam current profile as a function of static focusing magnetic field are shown in the following tables for both Ka band and V band. The simulations are conducted under a slow wave structure of 16 ladder, with given injected beam current and observed current after 16 ladders. A perfect focusing profile is no difference between input and output beam current. From the following results, we can clearly see that the required magnetic field intensity to maintain a perfect beam focusing is increased as the beam radius decreases and current intensity increases.

[0039] Table 2

	Ka Band (30 GHz) Pitch = 0.31797 mm Beam radius = 0.2459 mm		V Band (50 GHz) Pitch = 0.19022 mm Beam radius = 0.147 mm	
Injected beam	60 mA	80 mA	60 mA	80 mA
Beam current after 16 ladders				
B = 0.1 Tesla	38.2 mA			
B = 0.2 Tesla	55.7 mA			
B = 0.3 Tesla	58.3 mA	74.1 mA	55.7 mA	
B = 0.5 Tesla	60.0 mA	77.9 mA	58.3 mA	74.0 mA
B = 0.7 Tesla		78.0 mA	58.9 mA	77.8 mA
B = 0.9 Tesla		80.0 mA	60.0 mA	78.3 mA
B = 1.2 Tesla				80. mA

[0040] Although the following results show a big difference among different applied magnetic field, no significant differences are observed from beam image trajectories. So the final design should be always based on the detailed numerical results, not the qualitative image pictures.